

PATENT ABSTRACTS OF JAPAN

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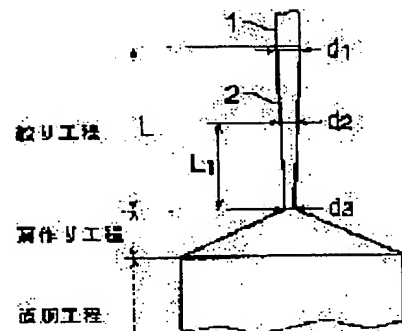
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(54) PULLING UP OF SILICON SINGLE CRYSTAL

(57)Abstract:

PROBLEM TO BE SOLVED: To prevent breakage of a crystal and minimally suppress increase of cost in a squeezing step for obtaining dislocation-free state in pulling up a silicon single crystal having crystal axis $\langle 110 \rangle$ by Czochralski process.

SOLUTION: In a squeezing step, a crystal diameter is squeezed to $< 2.0\text{mm}$ while applying magnetic field having $\geq 1,500$ gauss to a hot zone in a squeezing step. Vibration and change of temperature of the melt surface become small by application of magnetic field and breakage of crystal in solid-liquid interface which occurred from the past is prevented. In a shoulder-making step followed by the squeezing step, the strength of the applied magnetic field is gradually decreased and the strength of magnetic field is decreased to 0 until step is moved from the shoulder-making step to a drum-making step. Dislocation-free single crystal having crystal axis $\langle 110 \rangle$ is obtained by the method and increase of cost is minimally suppressed, because magnetic field is not applied in a step after the drum-making step.



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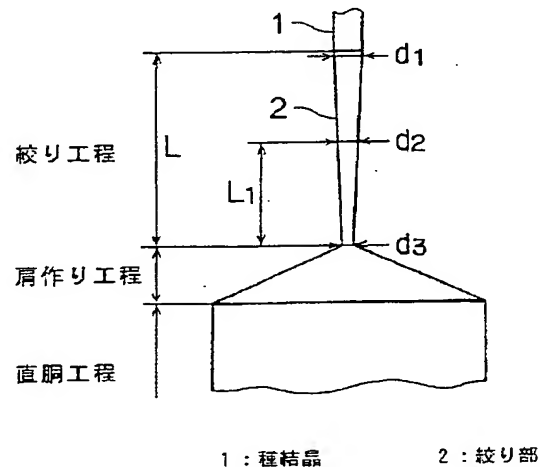
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(54) 【発明の名称】 シリコン単結晶の引き上げ方法

(57) 【要約】

【課題】 CZ法による結晶軸<110>シリコン単結晶の引き上げに当たり、無転位化するための絞り工程において結晶が切れないようにするとともに、コスト増加を最小限に抑えることができるようにする。

【解決手段】 絞り工程において、ホットゾーンに1500 Gauss以上の磁場を印加しつつ結晶直径を2.0 mm未満に絞る。磁場の印加により融液表面の振動、温度変動が小さくなり、従来から発生していた固液界面における結晶の切れが防止される。絞り工程に続く肩作り工程では、印加する磁場の強さを徐々に減じ、直胴工程に入るまでに磁場の強さを零とする。この方法により結晶軸<110>の無転位単結晶が得られ、直胴工程以降は磁場を印加しないためコスト増加は最小限に抑えられる。



【特許請求の範囲】

【請求項1】 チョクラルスキー法による結晶軸<110>シリコン単結晶の育成に先立って行う絞り工程において、1500 Gauss以上の磁場を印加し、融液表面の振動と温度変動とを抑制しつつ結晶直径を2.0 mm未満に絞ることを特徴とする結晶軸<110>シリコン単結晶の引き上げ方法。

【請求項2】 請求項1記載の絞り工程に続く肩作り工程において、印加する磁場の強さを徐々に減じ、直胴工程に入るまでに磁場の強さを零とすることを特徴とする結晶軸<110>シリコン単結晶の引き上げ方法。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】本発明は、結晶軸<110>シリコン単結晶の引き上げ方法に関する。

【0002】

【従来の技術】半導体素子の基板には主として高純度の単結晶シリコンが用いられているが、その製造方法の一つとして、るつば内の原料融液から円柱状の単結晶シリコンを引き上げるチョクラルスキー法（以下CZ法という）が知られている。CZ法においては、半導体単結晶引き上げ装置内に設置したるつばに原料である多結晶シリコンを充填し、前記るつばの周囲に設けたヒータによって原料を加熱溶解した上、シードチャックに取り付けた種結晶を融液に浸漬し、シードチャックおよびるつばを互いに同方向または逆方向に回転しつつシードチャックを引き上げて単結晶シリコンを成長させる。

【0003】CZ法を用いて大量に生産されている結晶軸<100>、<111>、<511>のシリコン単結晶に比べ、結晶軸<110>のシリコン単結晶は、種結晶から結晶を成長させて結晶中の転位を除去するいわゆる絞り工程において、結晶学的に転位の除去が困難である。その理由は、結晶軸<110>のシリコン単結晶においては結晶中の転位の方向が種結晶の軸方向、すなわち半導体単結晶引き上げ装置における鉛直方向と一致しており、結晶の成長方向と同じ<110>方向に転位が延びることによる。この対策として、絞り部の直径を3.~6 mmの範囲で細くしたり太くしたりして凹凸をつける、いわゆる多段絞りと呼ばれる手法が用いられている。図2は多段絞りを施した絞り部の形状を示す模式図で、種結晶1に続く絞り部2の直径を次第に細くした後、d1 = 4~6 mmに拡大し、次にd2 = 3~4 mmに絞る。このような操作を3回以上繰り返すことによって転位を除去し、肩作り工程に入る。

【0004】

【発明が解決しようとする課題】しかしながら、磁場を印加しない通常のホットゾーンにおける絞り工程では、シリコン融液の熱対流、不活性ガスの吹き付け、るつばの回転等の影響により、シリコン融液の表面が振動しているため、結晶直径を2.0~3.5 mmに絞ると、固

液界面で結晶が切れてしまうことが多い。また、結晶の切れを防止するため絞り径を太くすると、転位を除去することができない。このため、結晶軸<110>のシリコン単結晶の引き上げを量産レベルで行うことは困難と考えられてきた。

【0005】量産レベルでの結晶軸<110>のシリコン単結晶引き上げを可能とするには、絞り工程において結晶が切れないようにすることと、これに伴うコスト増加を最小限に抑えることの2点が重要課題となる。本発明は上記従来の問題点に着目してなされたもので、前記課題を解決することができる結晶軸<110>シリコン単結晶の引き上げ方法を提供することを目的としている。

【0006】

【課題を解決するための手段】上記目的を達成するため、本発明に係る結晶軸<110>シリコン単結晶の引き上げ方法は、CZ法による結晶軸<110>シリコン単結晶の育成に先立って行う絞り工程において、1500 Gauss以上の磁場を印加し、融液表面の振動と温度変動とを抑制しつつ結晶直径を2.0 mm未満に絞ることを特徴としている。

【0007】また、上記絞り工程に続く肩作り工程において、印加する磁場の強さを徐々に減じ、直胴工程に入るまでに磁場の強さを零とすることにした。

【0008】

【発明の実施の形態および実施例】本発明は、融液の対流等によって起こる融液表面の振動を抑え、融液表面の温度変動を小さくするためホットゾーン全体に磁場を印加する磁場下引き上げ法（以下MCZ法という）によって絞り工程を処理するものである。MCZ法によりホットゾーン全体に磁場を印加すると、磁力線に直交する導電体融液の有効動粘性係数が増大し、融液の対流が抑制されて融液表面の温度変動が低減する。このため、磁場を印加しない場合の融液表面の温度変動が約1.5℃であるのに対し、磁場の強さを1500 Gaussにすると、融液の対流が抑制されて前記温度変動を約0.1℃まで低減させることができる。その結果、1500 Gauss以上の磁場下では、通常のCZ法で実現困難な結晶直径、すなわち結晶直径を1.5~2.0 mm未満まで細く絞ることが可能となる。これにより無転位の結晶軸<110>シリコン単結晶を量産レベルで安定して育成することができる。

【0009】上記により絞り工程を良好に進めることは可能となるが、磁場の印加によるコストアップは避けられない。このため量産技術の確立には、絞り工程の後工程で磁場を徐々に減じる技術が必要となる。ホットゾーン全体に印加する磁場の強さを徐々に減じて行くと、融液の対流が起こり始め、融液表面の温度が上昇し始めるため、結晶直径が細くなる傾向がある。そこで、所定の結晶直径を維持したまま単結晶を育成する直胴工程に入

ってから磁場を減じるよりも、直胴工程の前の肩作り工程が終了するまでの間に磁場を0 Gaussまで減じることが好ましい。このようにすれば、直胴工程における結晶直径の制御が容易となる。

【0010】次に、本発明に係る結晶軸<110>シリコン単結晶の引き上げ方法の実施例について、図面を参照して説明する。図1は、本発明の引き上げ方法によって製造される結晶軸<110>シリコン単結晶の上端部分を示す模式図である。

【0011】半導体単結晶引き上げ装置のチャンバ内を14~20 Torrに真空引きし、不活性ガスとして3~5×10⁻¹ Nm³/分のArガスを導入した。ホットゾーン全体に1500~4000 Gaussの磁場を印加し、融液に種結晶1を浸漬してなじませた後、図示しないシードチャックを徐々に引き上げて絞り工程を開始した。絞り工程開始時における絞り部2の結晶直径d1は8 mmで、これを徐々に細くし、直径d2を2.0 mm、絞り工程終了時の結晶直径(最小径)d3を1.5~2.0 mm未満とした。絞り部2の全長Lは50~300 mmとした。前記長さLのうち結晶直径が2.0 mm未満の部分、すなわち結晶直径d2からd3までの長さL1は10~100 mmである。また、結晶直径が2.0 mm未満の部分における結晶引き上げ速度は5.0~6.0 mm/分とした。

【0012】直胴部の直径が103 mmの単結晶を引き上げる場合、絞り工程に続く肩作り工程に要する時間を30~100分とし、前記所要時間に比例させて徐々に磁場を減じた。たとえば、磁場の強さが1500 Gaussで肩作り所要時間を100分とした場合は15 Gauss/分、磁場の強さが4000 Gaussで肩作り所要時間が30分の場合は140 Gauss/分の割合で徐々に磁場を減じ、肩作り工程が終了して結晶直径が103 mmに達したときに磁界が零となるように制御した。

【0013】上記方法を用いた結果、絞り工程における結晶の切れが発生せず、安定した絞りを行うことができた。また、得られた結晶軸<110>シリコン単結晶に*

*は転位が認められなかった。これは、絞り工程において絞り部2の結晶直径が2.0 mm未満の部分の長さを10 mm以上としたことによって転位が除去されたためである。

【0014】

【発明の効果】結晶軸<110>のシリコン単結晶は、結晶中の転位の方向と結晶成長方向とが同一であるため、絞り工程で安定して無転位化を図ることは困難で、量産には不向きとされ、結晶軸<100>、<111>、<511>のシリコン単結晶に比べて量産技術の確立が遅れている。そして、従来法で<110>を引き上げると固液界面切れが多発し、100本中90本が不良となり、10本がやっと引き上げ出来た。(良品率10%)

しかし、絞り工程で1500 Gauss以上の磁場を印加することにより、従来のCZ法では実施が困難な結晶直径1.5~2.0 mm未満まで絞ることが可能となり、その結果、結晶軸<110>のシリコン単結晶の引き上げが容易となり、実施してみると、100本中100本が良品となった。(良品率100%)

また、次工程の肩作り工程で徐々に磁場を減じ、直胴工程に入る前に磁界をゼロにすることにより、必要最小限のコストアップに止めることができる。従来のMCZ法に比べ電気代が半以下で済み経済的効果も多大である。従って、高密度にデバイスを集積させることのできる<110>ウェーハの量産化が可能となる。

【図面の簡単な説明】

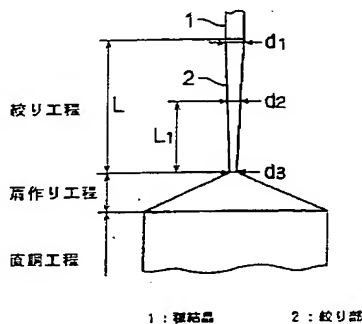
【図1】本発明の引き上げ方法によって製造される結晶軸<110>シリコン単結晶の上端部分を示す模式図である。

【図2】多段絞りを施した絞り部の形状を示す模式図である。

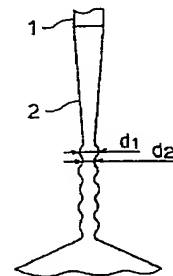
【符号の説明】

- 1 種結晶
- 2 絞り部

【図1】



【図2】



(4)

特開平 9-165298

【手続補正書】

【提出日】平成 8 年 2 月 26 日

【手続補正 2】

【補正対象書類名】明細書

【補正対象項目名】発明の名称

【補正方法】変更

【補正内容】

【発明の名称】
方法

シリコン単結晶の引き上げ

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CLAIMS

[Claim(s)]

[Claim 1] An approach to pull up the crystallographic-axis <110> silicon single crystal characterized by extracting a crystal diameter to less than 2.0mm, impressing a magnetic field 1500 gauss or more, and controlling the oscillation and temperature fluctuation on the front face of melt in the drawing process performed in advance of training of the crystallographic-axis <110> silicon single crystal by the Czochralski method.

[Claim 2] An approach to pull up the crystallographic-axis <110> silicon single crystal characterized by making the strength of a magnetic field into zero by the time it reduces the strength of the magnetic field to impress gradually in the shoulder making-process following a drawing process according to claim 1 and goes into a body process.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to an approach to pull up a crystallographic-axis <110> silicon single crystal.

[0002]

[Description of the Prior Art] Although the single crystal silicon of a high grade is mainly used for the substrate of a semiconductor device, the Czochralski method (henceforth a CZ process) which pulls up cylinder-like single crystal silicon from the raw material melt in a crucible is known as one of the manufacture approach of the. Rotating [in a CZ process, fill up the crucible installed in semiconductor single crystal raising equipment with the polycrystalline silicon which is a raw material, after carrying out the heating dissolution of the raw material at the heater formed in the perimeter of said crucible, the seed crystal attached in the seed chuck is immersed in melt, and] a seed chuck and the crucible of each other to this direction or hard flow, a seed chuck is pulled up and single crystal silicon is grown up.

[0003] Compared with the silicon single crystal of the crystallographic axis <100> currently produced by the large quantity using the CZ process, <111>, and <511>, clearance of a rearrangement is crystallographically difficult for the silicon single crystal of a crystallographic axis <110> in the so-called drawing process which a crystal is grown up from seed crystal and removes the rearrangement under crystal. In the silicon single crystal of a crystallographic axis <110>, the direction of the reason of the rearrangement under crystal corresponds with the shaft orientations of a vertical of seed crystal, i.e., the direction in semi-conductor single crystal raising equipment, and it is because a rearrangement is prolonged in the same <110> directions as the direction of crystal growth. The technique called the so-called multistage drawing which makes the diameter of a converging section thin in 3-6mm, or makes it thick as this cure, and gives irregularity is used.

Drawing 2 is the mimetic diagram showing the configuration of a converging section where multistage drawing was performed, after it makes thin gradually the diameter of the converging section 2 following seed crystal 1, is expanded to $d1 = 4-6\text{mm}$, and then is extracted to $d2 = 3-4\text{mm}$. By repeating such actuation 3 times or more, a rearrangement is removed and it goes into a shoulder making-process.

[0004]

[Problem(s) to be Solved by the Invention] However, at the drawing process in the usual hot zone which does not impress a magnetic field, since the front face of silicon melt is vibrating, if a crystal diameter is extracted to 2.0-3.5mm under the effect of the heat convection of silicon melt, blasting of inert gas, a revolution of a crucible, etc., a crystal will go out by the solid-liquid interface in many cases. Moreover, a rearrangement is unremovable, if the diameter of drawing is made thick in order to prevent the piece of a crystal. For this reason, it has been thought that it is difficult to raise the silicon single crystal of a crystallographic axis <110> on mass production level.

[0005] In order to enable silicon single crystal raising of the crystallographic axis <110> in mass production level, two points, suppress [making it a crystal not go out in a drawing process and] the increment in cost accompanying this to the minimum, become an important problem. This invention was made paying attention to the above-mentioned conventional trouble, and aims at offering an approach pulling up the crystallographic-axis <110> silicon single crystal which can solve said

technical problem.

[0006]

[Means for Solving the Problem] It is characterized by extracting a crystal diameter to less than 2.0mm in the drawing process performed in advance of training of the crystallographic-axis <110> silicon single crystal by the CZ process, an approach pulling up the crystallographic-axis <110> silicon single crystal concerning this invention, in order to attain the above-mentioned object impressing a magnetic field 1500 gauss or more, and controlling the oscillation and temperature fluctuation on the front face of melt.

[0007] Moreover, in the shoulder making-process following the above-mentioned drawing process, it decided to make the strength of a magnetic field into zero, by the time it reduces the strength of the magnetic field to impress gradually and goes into a body process.

[0008]

[The gestalt and example] of implementation of invention In order that this invention may suppress an oscillation of the melt front face which happens by the convection current of melt etc. and may make small temperature fluctuation on the front face of melt, it is extracted by the magnetic field under-coating raising method (henceforth the MCZ method) for impressing a magnetic field to the whole hot zone, and processes a process. If a magnetic field is impressed to the whole hot zone by the MCZ method, the effective coefficient of kinematic viscosity of the conductor melt which intersects perpendicularly with line of magnetic force will increase, the convection current of melt will be controlled, and the temperature fluctuation on the front face of melt will decrease. For this reason, if the strength of a magnetic field is made into 1500 gauss to the temperature fluctuation on the front face of melt when not impressing a magnetic field being about 1.5 degrees C, the convection current of melt is controlled and said temperature fluctuation can be reduced to about 0.1 degrees C. Consequently, under a magnetic field 1500 gauss or more, it becomes possible to extract thinly to less than 1.5-2.0mm, the usual a crystal diameter with implementation difficult at a CZ process, i.e., crystal diameter. Thereby, on mass production level, it is stabilized and the crystallographic-axis <110> silicon single crystal of a non-rearrangement can be raised.

[0009] Although it becomes possible to extract by the above and to advance a process good, the cost rise by impression of a magnetic field is not avoided. For this reason, the technique which reduces a magnetic field gradually at an after [a drawing process] process is needed for establishment of mass production technology. If the strength of the magnetic field impressed to the whole hot zone is reduced gradually and it goes, since the convection current of melt will begin to take place and the temperature on the front face of melt will begin to rise, there is an inclination for a crystal diameter to become thin. Then, it is desirable to reduce a magnetic field to 0 gauss, by the time the shoulder making-process in front of a body process is completed rather than it reduces a magnetic field after going into the body process which raises a single crystal, with a predetermined crystal diameter maintained. If it does in this way, control of the crystal diameter in a body process will become easy.

[0010] Next, the example of an approach to pull up the crystallographic-axis <110> silicon single crystal concerning this invention is explained with reference to a drawing. Drawing 1 is the mimetic diagram showing the upper bed part of the crystallographic-axis <110> silicon single crystal manufactured by the approach to pull up this invention.

[0011] Vacuum suction of the inside of the chamber of semi-conductor single crystal raising equipment was carried out to 14 - 20Torr, and Ar gas for $3 - 5 \times 10^{-2} \text{Nm}^3$ was introduced as inert gas. The 1500-4000 gauss magnetic field was impressed to the whole hot zone, after immersing and familiarizing seed crystal 1 with melt, the seed chuck which is not illustrated was pulled up gradually, and was extracted, and the process was started. Crystal diameter d1 of the converging section 2 at the time of drawing process initiation It is 8mm, this is gradually made thin, and it is a diameter d2. 2.0mm and crystal diameter d3 at the time of drawing process termination (diameter of min) It could be less than 1.5-2.0mm. The overall length L of a converging section 2 was set to 50-300mm. the inside of said die-length L -- a crystal diameter -- the part d2, i.e., the crystal diameter, of less than 2.0mm from -- d3 up to -- die length L1 It is 10-100mm. Moreover, the crystal diameter considered the crystal raising rate in a less than 2.0mm part as a part for 5.0-6.0mm/.

[0012] When pulling up the single crystal whose diameter of the body section is 103mm, made into

30 - 100 minutes time amount which the shoulder making-process following a drawing process takes, it was made to be proportional to said duration, and the magnetic field was reduced gradually. For example, when the strength of a magnetic field made a shoulder making-duration 100 minutes by 1500 gauss, the strength of a 15 gauss a part for /and a magnetic field reduces a magnetic field gradually at 140 gauss a rate for /by 4000 gauss when a shoulder making-duration is 30 minutes, a shoulder making-process was completed and a crystal diameter amounted to 103mm, it controlled so that a field served as zero.

[0013] As a result of using the above-mentioned approach, the piece of the crystal in a drawing process was not generated, but stable drawing was able to be performed. Moreover, a rearrangement was not accepted in the obtained crystallographic-axis, <110> silicon single crystal. This is because the rearrangement was removed, when the crystal diameter of a converging section 2 set the die length of a less than 2.0mm part to 10mm or more in the drawing process.

[0014]

[Effect of the Invention] Since the silicon single crystal of a crystallographic axis <110> has the same direction and crystal growth direction of a rearrangement of [under crystal], it was difficult to be stabilized at a drawing process and to attain non-rearrangement-ization, it was made unsuitable for mass production, and is behind in establishment of mass production technology compared with the silicon single crystal of a crystallographic axis <100>, <111>, and <511>. And when <110> was pulled up with the conventional method, solid-liquid interface pieces occurred frequently, 90 became poor among 100, and ten have raised at last. (10% of rates of an excellent article)

However, operation was enabled to extract to the difficult crystal diameter of less than 1.5-2.0mm in the conventional CZ process by impressing a magnetic field 1500 gauss or more at a drawing process, consequently raising of the silicon single crystal of a crystallographic axis <110> became easy, and when carried out, 100 became an excellent article among 100. (100% of rates of an excellent article)

Moreover, before reducing a magnetic field gradually at the shoulder making-process of degree process and going into a body process, it can stop to a necessary minimum cost rise by making a field into zero. Compared with the conventional MCZ method, electrical charges can be managed below with one half, and economical effectiveness is also great. Therefore, the fertilization of <110> wafers on which high density can be made to accumulate a device is attained.

[Translation done.]

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] It is the mimetic diagram showing the upper bed part of the crystallographic-axis <110> silicon single crystal manufactured by the approach to pull up this invention.

[Drawing 2] It is the mimetic diagram showing the configuration of a converging section where multistage drawing was performed.

[Description of Notations]

- 1 Seed Crystal
- 2 Converging Section

[Translation done.]

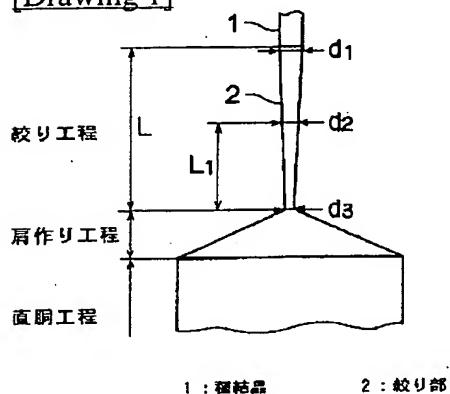
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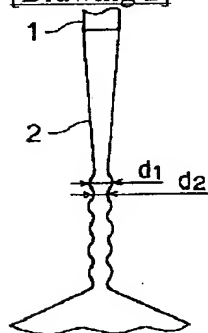
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DRAWINGS

[Drawing 1]



[Drawing 2]



[Translation done.]